CENTRE DE COOPERATION

INTERNATIONALE EN RECHERCHE

AGRONOMIQUE POUR LE DEVELOPPEMENT

CIRAD – FLHOR

TA 50 / PS 4 34398 - MONTPELLIER Cedex 5

REPORT OF THE MISSION TO MALI ON THE COMPLEX OF FRUIT FLIES (DIPTERA-TEPHRITIDAE) ASSOCIATED WITH MANGO TREES

On behalf of the Centre Agro-Entreprise (CAE)

a CAE / SEG / USAID Project

TABLE OF CONTENTS

SUMMARY

A USAID financed study of fruit flies prevalent in Malian mango orchards began during the 2000 production season and was conducted by the Centre Agro-Entreprise.

Annual production in Mali is estimated at 100,000 tons but rarely is more than 1% of this production exported. The principal reasons for the low level of exports is related to both structural and phytosanitary problems, specifically those stemming from fruit fly infestation, resulting in losses estimated at more than 50% of production.

The principal objective of this six month study concerning the Tephritida*e* species of fruit fly is the establishment of an integrated pest management system using spot treatments. In order to accomplish this, it was necessary to identify the species responsible for mango spoilage in the three principal production zones (Sikasso, Bougouni, Bamako).

1226 mangos which had been subject to fruit fly attacks were harvested and placed under observation between April and September, representing a total weight of 602 kgs. 7518 adult fruit flies were harvested from the mangos under observation. Based on observations carried out using a high powered microscope, six species of Tephritidae were identified :

- *Ceratitis cosyra* (Walker)
- *Ceratitis quinaria* (Bezzi)
- *Ceratitis silvestrii* Bezzi
- *Ceratitis rosa* Karsch
- *Ceratitis anonae* Graham
- *Ceratitis ditissima* (Munro)

The species which were the most prevalent and precocious were the first three cited in the above list, thus they should be accorded priority for programmed follow up work.

The establishment of a trapping system proved effective from the time that the traps were first installed in the three orchards. 60 traps were put into place in each of the three orchards of which 36 were dry traps and 24 were liquid traps. The 180 traps captured a total of 128,998 adult Tephritidae belonging to 13 different species ; the 6 species listed above which are most closely associated with mangoes represented 99% of captures.

The spoilage resulting from Tephritidae attacks was estimated by mango variety and, in particular, for Kent, Keitt and Brooks. The analysis indicated that spoilage could reach 50% of production for Kent and Keitt varieties and more than 60% for Brooks during the middle of the production season.

Spot treatments began at the end of June in the three studied sites and results were encouraging when compared to the control fields. The principal limiting factor inherent

in this type of intervention is rainfall whose negative impact can be lessened by the application of treatments earlier in the growing season.

On site training activities were well received by producers (11 villages), purchasing agents and exporters and radio programs were aired at the national level. The interest of participants was evident at all levels.

The principal recommendations concern extending the scope of the monitoring and early warning systems from 3 to 9 sites during next year and to assure that traps are installed during January 2001, at the outset of the next production season. Similarly, the program should be totally operational from the time fruits first appear in order to apply spot treatments so as to assure maximum protection of fruit production.

ACKNOWLEDGEMENTS

First off, my heartfelt thanks to all the Malian planters : those we simply spent a few moments with, walking around their orchards ; those with whom we worked during the training sessions in their respective villages ; those who came to see us at the entomological laboratory in Sikasso ; those for whom we have carried out timely interventions, and those in whose orchards we were finally able to see our experiments through for 17 straight weeks : in the latter case, I refer to Mssrs. Soumaïla Diarra in Waibera, Fanto Traoré in Konyini and Bakary Ballo in Madina. My gratitude and appreciation go to them all for their openness, enthusiasm and great motivation.

I should like to express my deep appreciation and gratitude to Mr Cheikh Soumaré, the Head of the Sikasso branch, for his interest in and monitoring of our actions, shown both in his skill as an interpreter in the villages, and in his ongoing administrative support.

My sincere thanks to Mr Issa Cissé, not only for his skills as a driver, but also for his unfailing aid on the ground during our weekly review of the traps.

I should like to express my satisfaction and gratitude to Mr Karim Abdul Sanogo, Sales Executive with Mali Yiriden in Sikasso, for his impeccable knowledge of the orchards of Sikasso, as well as for his unfailing good spirits.

I should also like to thank Mr Fatogoma Sanogo, Researcher at the IER – Sikasso, for his technical cooperation, as well as Mssrs Mémé Togola and Nangazana Kone for their continuing interest throughout our work.

My personal thanks go to Mr Moctar Boukenem, who accompanied and guided me with an unerring touch during the first few weeks of surveys and visits, Mssrs Andrew Lambert and Geoffrey Livingston, who provided unfailing support, without forgetting the administrative staff of the CAE, who extended the warmest of welcomes to me on each of my stays in Bamako.

INTRODUCTION

Malian production of mangoes, estimated at 100 000 tons per annum, is to a large extent composed of varieties which are sought after for export, such as Amélie, Kent and Keitt. Despite this sizeable potential, the total amount exported annually, both by air and by sea, rarely exceeds 1000 tons.

One of the main reasons for this state of affairs on the phytosanitary level are the fruit flies which inflict sizeable losses during production, and which may cause partial or total destruction of the exported pallets. In the latter case, Mali's reputation as a reliable source of supply may be called into question.

In order to permit a substantial increase in mango export volumes, therefore, an effective method of controlling the fruit fly – one which is environmentally sound, and which producers can afford – must be put forward and tested. It is with this objective in mind that this operation is proposed.

In part one we shall outline a general introduction to the zones studied and the phytosanitary problems peculiar to the mango tree, as well as providing a brief synthesis of the studies carried out on this unassuming yet formidable family of insects.

In part two we shall set out the problem, the stakes and the objectives of this important study within the mango sector.

In part three we shall specify the materials and methods used to achieve the objectives which we have set ourselves.

In part four we shall develop the results obtained for each objective, results which we shall then discuss in the light of studies available in this field.

In the fifth and last part, we shall focus on the main recommendations made in the pursuit of this type of operation.

PART ONE : GENERAL

1.1. INTRODUCTION OF THE ZONES STUDIED IN MALI :

1.1.1 Survey of the geography and climate :

Mali covers an area of 1,240,142 km², only one quarter of which is arable land. It is a landlocked country, with no access to the sea save chiefly for Abidjan, and to a lesser extent Dakar, ports which serve as the lungs of Mali owing to their international exchanges.

Two river basins provide Mali with a territory of 50,000 km^2 drained by the Niger and Senegal rivers (and their tributaries). The Niger river occupies a preeminent place in the agricultural development of the country, running through a large portion of the latter and bringing the arid land to life.

Rainfall may be viewed as the key determining factor for agricultural production as a result of its climatology. In point of fact, ranging from north to south, Mali consists of three major zones : Saharan (2/3 of the country), Sahelian and Sudanian ; the latter, relatively small zone is the most suitable for raising food or export crops.

This geographical division into arid zones renders the country particularly vulnerable to climatic uncertainties, all the more so as we have witnessed a substantial drop in isohyets towards the south over the last 40 years.

1.1.2 Survey of agriculture :

Mali's economy is still based to a large extent on the agro-pastoral sector, which contributes 43% of the GDP (Marchés Tropicaux, 2000). This sector accounts for nearly 70% of the value of exports and provides a source of income for nearly 80% of the population. During the last three years, the growth in GDP is due to the primary sector, and more particularly to agricultural foodstuff (millet/rice) and industrial (cotton) production. The potential of irrigable land for agricultural production is estimated at 2.2 million hectares from the two major river systems Niger / Bani and Senegal (*Marchés Tropicaux*, 2000).

The surface area occupied by food agriculture and the production volumes of the latter during the last three harvests highlights the importance of this sector of the Malian economy ; but the growth of the sector remains low, since it is still based essentially on the increase of the land area used, and not on a significant increase in productivity.
The fruit and vegetable sector has been revitalised : Mali exports mangoes and green beans to Europe, and potatoes and shallots to the subregion.

1.1.3 Location of the test sites :

The main zones of production of the mango tree, *Mangifera indica* L. (Anacardiaceae), are to be found around Sikasso, Bougouni and Bamako (**Appendix 1**), zones which are highly favorable for its cultivation. A survey carried out by APROFA (Coulibaly, 1999) revealed an area devoted to mango cultivation in the Third Region of 21,953 hectares, or over two billion square feet. This substantial report should serve as a springboard for the regeneration of the mango sector in this region.

Thus, in the Third Region, we have, from largest to smallest area of mango cultivation, the zones of Sikasso (with 28.38% of the area), Bougouni (27.83%), Yanfolila (20.20%), Koutiala (12.64%), Kadiolo (9.05%), Kolondieba (1.14 %) and Yoroso (0.76 %). We have no figures for the Bamako – Koulikoro region.

During our research, three sites were chosen (**Figure 1**) : Waîbera, about 40 km south of Sikasso, Madina, about 30 km west-southwest of Bougouni, and Konyini, approximately 20 km east of Bamako.

The coordinates of these sites are as follows :

- Waibera : 11 degr. 11 min. North, 5 degr. 32 min. West
- Madina : N 11. 20 W 7. 39
- Konyini : N 12. 38 W 7. 50

1.2 PATHOGENS AND PESTS OF MANGO IN MALI :

1.2.1 Pathogenic organisms :

Different symptoms of the action of pathogens on fruits have been observed. The most common is anthracnose (*Colletotrichum* sp) which is characterized by black spots with a sappy discharge, or by black streaks originating at the peduncle. This disorder becomes more and more widespread as the wet season gets underway, especially in the southern zones of the Third Region.

Another fairly common disorder involves the peduncular or stem zone of the fruit, hence its name of stem-end rot (*Lasiodiplodia* sp). This rot is greasy in appearance, ash-gray in color, and extends from the point of insertion of the peduncle. Mango trees belonging to the variety ‘Kent’ and developing in the wet bottom lands relatively often bear fruits with these symptoms.

Lastly, scab, a less frequent disorder than the preceding two, is characterized by corky spots on the epidermis of the fruit, appearing during the wet season.

1.2.2. The insects :

The mango tree harbors numerous pest species, including the Hemiptera of the family Alydidae with the species *Tupalus fasciatus* and *Leptocoris* sp.; the Hemiptera Coccoidea comprising several species, the most dangerous of which, however, is indisputably the fruit tree mealybug *Rastrococcus invadens* ; the Diptera of the family Tephritidae (fruit flies) ; and the xylophagous Coleoptera of the family Scolytidae and Bostrichidae.

Mealybugs : The fruit tree mealybug, *Rastrococcus invadens*, is a formidable pest whose sighting in Sikasso on several mango trees was reported at the beginning of the year by J.Y. REY (pers. comm.). It was also found by us on the outskirts of the town in several private gardens, but with none of the same severity seen in Côte d'Ivoire, where it leads, among other things, to the presence of sooty molds on the leaves and a steep drop in production the following year. In Sikasso, we noted the presence of certain of these parasitoids in particular :

- The Encyrtidae *Gyranusoidea tebygi* Noyes, which was introduced to Benin ;
- The Aphelinidae *Marietta leopardina* Motschulski, which is more polyphagous than the preceding one.

Nevertheless, we feel it is important to ensure that an alert and control cell is set up to combat this species of mealybug, which is easily differentiated from other species of scale insects.

Fruit flies : The greatest damage to mango production in Mali is still caused by fruit flies, whether in mango orchards in the south bordering on Côte d'Ivoire, or in orchards in the Bamako area, which have a more Sahelian climatology.

1.3. BRIEF SYNTHESIS OF KNOWLEDGE ACQUIRED ON THE TEPHRITIDAE :

1.3.1 Economic importance, taxonomy, biology and behaviour, methods of control :

1.3.1.1. Economic importance :

In the order Diptera, the family Tephritidae is one of the most important in economic terms, comprising over 4000 species divided among 500 genera and distributed throughout the temperate as well as tropical regions. The overwhelming majority of the larvae of this family is phytophagous, feeding chiefly on soft fruits.

The Tephritidae inhabit all regions where fruit trees grow. Their economic impact may be summed up as follows :

- the adults attack fruit grown for commercial purposes, as well as wild fruit ;
- certain species have become pests of fruit trees cultivated far from their area of origin ;

- drastic conditions for fruit imports are essential in order to limit the spread and expansion of certain particularly formidable species ;
- certain quarantine and disinfection conditions imposed on the exported fruit constitute injurious limiting factors for certain exporting countries.

Estimates of economic losses from fruit flies have not yet been quantified, but those involved in the fruit trade, from upstream to downstream, recognize the scale of the damage inflicted by these pests. In the case of Australia, for example, if no control measures were implemented, losses sustained from fruit flies would amount to more than 12% of the price of the harvest (White & Elson-Harris, 1992).

1.3.1.2. Taxonomy :

Within the family Tephritidae, adults are characterized by the following morphological characteristics (Delvare & Aberlenc, 1989) :

- ⇨ wings almost always speckled,
- ⇨ presence of ocelli,
- ⇨ well developed arista,
- ⇨ tip of subcostal vein bent at an angle,
- ⇨ absence of vibrissa,
- ⇨ abdomen composed of five or six visible segments, ending in the case of the female in a pointed ovipositor.

Species of the genus *Ceratitis* which interest us here belong to the subfamily Ceratitinae.

1.3.1.3. Biology and behavior :

The most important Tephritidae are often largely polyphagous insects such as *Ceratitis capitata* (Wiedemann) with over 250 species of host plants, *Bactrocera dorsalis* (Hendel) with 173 species, and *Ceratitis rosa* Karsch with some fifty species (White & Elson-Harris, 1992).
There are, however, exceptions : thus, *Bactrocera oleae* (Gmelin), a monophagous species of the Mediterranean basin and other temperate zones, is a major pest of the olive tree alone, in the Mediterranean region.

Univoltine species (those producing a single generation per year) are species inhabiting the temperate regions, often monophagous, and having a winter diapause, as is the case for the olive fruit fly *B. oleae.*

Multivoltine species (those producing several generations per year) are polyphagous and inhabit tropical and subtropical regions without undergoing a developmental pause : this is the case for the species of ceratites which we harvested and raised in Mali on mangoes.

Tephritidae locate the fruit they require for food and egg-laying by a series of visual, olfactory and tactile stimuli, the importance and sequence of which are peculiar to each species, and which also depend on climatic factors.

Female Tephritidae (**Photo 1**) are characterized by a long, extensible ovipositor allowing them to pierce the fruit and deposit their eggs in its pulp. The eggs hatch after several days, depending on the temperature, and doubtless also upon the physiological stage of the host fruit. Issuing from the eggs are whitish larvae (**Photo 2**), apodal but able to hop, which pass through three larval stages before transforming into pupae in the soil. At 25°C, the Mediterranean fruit fly *C. capitata* will take approximately one month to produce one complete generation from egg to egg. This species may live for several months and lay several hundred eggs, depending upon food supply (larval and imaginal) and various abiotic and biotic factors. Lifespan is likewise peculiar to each species, with the polyphagous and multivoltine species having greater longevity (White & Elson-Harris, 1992).

1.3.1.4. Pest Management Methods :

- <u>Population detection</u> **:** The traps for capturing adult Tephritidae are the best tools for population detection. An impressive number of types of traps has been developed and tested with highly variable results, not all of which have been published. The main ones are :

⇨ The “visual trap”, which associates an attractive color (yellow) with a proteoammoniated attractant, is still being researched ; one variant of this is the “Tephri-trap” with an insecticide platelet placed in a pod under its cover (**Photo 3**).

⇨ The “McPhail trap” (**Photo 4**), which uses a liquid attractant, is the archetype of the fruit fly trap (McPhail, 1937) and is still in use ; numerous variants of this sort of trap have been developed over the years.

⇨ The “Steiner trap”, which uses a sexual pheromone or parapheromone as an attractant, was invented by Steiner (1957), and allows large numbers of males to be trapped, which are then killed by an insecticide ; the Israeli trap, perfected by D. Nadel, is a variant of this trap, as is the Addis trap (**Photo 5**) (Quilici, 1992).

⇨ The “birdlime trap”, for which Frick (1952) was a trailblazer, consisted of a male attractant with sticky inserts against which the adults were trapped ; the “Jackson” limed trap is an improvement of this.

The three essential criteria for optimal population detection concern the choice of attractant together with the type of trap, suitably matched the to the chosen trapping site. These choices will increasingly be made thanks the mathematical modelling of said problem, linked to one or more species of fruit flies.

- Population estimates **:** As far as adults are concerned, several types of traps may be used : those capturing adults in the process of emerging in an orchard or field (Southwood, 1978) ; others using attractant colors and chemical compounds. The truth is that none of them is really satisfactory for estimating the size of populations developing in a given zone. The only reliable technique for arriving at this estimate is the marking-release-recapture technique (Itô & Koyama, 1982).

All marking and recapture methods have the following chief constraints : the technique must not affect the longevity or the behavior of the adult ; the marking must be indelible ; and the probability of capturing marked and non-marked fruit flies must be the same. The traps are then baited with attractants commonly used for the Tephritidae.

- Integrated pest management (I. P. M.) **:** Initiating an integrated pest management program aimed at a given species of Tephritidae involves the study of its population trends, the estimate of damage to the crop, the definition of its economic damage threshold, and a good knowledge of the agrosystem in question. Quite clearly, insecticide treatments are not ruled out, and must be optimized according to the phenology and population dynamics of the pest, while remaining compatible with the growing environment ; moreover, they must be economically justified.

Chemical control methods, which are unsatisfactory for a number of reasons, are now being replaced by other pest control means. Let us consider the example of *B. oleae*, a monophagous pest against which the following have been used (Kapatos, 1989) :

⇨ Release of beneficial species (= biological pest control) such as *Psyttalia concolor* (Szépligeti),
⇨ Release of sterile males (= management by means of autocide) of *B. oleae*,
⇨ Mixed traps with visual and olfactory attractants (= biotechnical control).

These three control methods (biological, autocidal and biotechnical) represent several of the components of integrated pest management.
Lastly, spot treatments (protein hydrolysate + insecticide) may constitute an invaluable aid for fruit fly control owing to their efficacy, moderate cost, and respect for consumer health and the environment.

1.3.2. Tephritidae closely associated with the mango tree in Mali :

The annual reports of the IER (Institute of Rural Economy) of Mali, issued by the Ministry of Agriculture on the subject of crop protection, allow us to take stock of Mr B. Diarra's and Mr M. Noussourou's series of reports on fruit flies from 1986 to 1989. Their reports have subsequently been summarized and published in Sahel IPM (Noussourou & Diarra, 1995). Their collections have enabled the identification of 4 species of Tephritidae closely associated with the mango tree: to wit, *Pardalaspis cosyra*, *P. punctata, P. sylvestrii* and *Pterandrus sp aff. rosa*.

Their study also focused on the trapping of fruit flies with yellow plates in the Bamako and Sikasso zones, which allowed them to highlight fluctuations in captures of the species *P. cosyra*. Interesting behavioral observations were made concerning this species, as well as proposals for integrated pest management.

PART TWO : PROBLEMS AND OBJECTIVES OF THIS STUDY

2.1. PROBLEMS :

The Centre Agro-Entreprises (CAE), financed by the USAID, is an organization providing support, technical assistance and advice to Malian agribusinesses. Chief among its numerous objectives may be cited its intention of strengthening the capacity and performance of agribusinesses in order to achieve effective growth of value-added in the fruit and vegetable subsector (among others), as well as strengthening the marketing of commodities from this subsector.

Mali, second largest ACP exporter to the EU, nevertheless trails far behind Côte d'Ivoire as a mango supplier to the European market. Although Malian production remains considerable, at approximately 100,000 tons of fruit on average each year, its exports have never exceeded 1000 tons per annum. Thus in 1999, according to Coleacp, Mali exported 936 tons of mangoes, as compared with the 11,100 exported by Côte d'Ivoire.

The marginalization of Mali on the export markets is not due to a lack of exportable production ; in point of fact, the Amélie, Kent and Keitt varieties currently represent 56% of the 21,953 hectares occupied by mango trees in the Third Region (Coulibaly, 1999). Furthermore, there is a time lag in the production period of the varieties mentioned between Mali and Côte d'Ivoire, which puts them in a thoroughly competitive position (**Figure 2**).

The main reasons which could be advanced to explain why Côte d'Ivoire mango exports are 5 – 12 times greater (depending on the harvest) than those of Mali, despite the sizeable theoretical potential of the latter country, are various in nature, having geographical, logistic, socio-economic, socio-political, financial, and lastly, qualitative causes. It is obvious that fruit-fly infestations, by reducing production levels by nearly 50%, are one of the major limiting factors in terms of quality.

In actual fact, certain Tephritidae species present in West Africa (and therefore in Mali) may present a risk of acclimatization in the Mediterranean region from April to September, and are thus deemed by Community regulations to be quarantine organisms (Directive No. 77 / 930 EEC). Thus, fruits which are apparently healthy at the time of their dispatch in container ships may actually harbor eggs which are difficult to spot at the time of packing and which are capable of developing into third-stage larvae or pupae upon arrival in Marseilles. Hence the unilateral decisions taken to the detriment of the exporter by the SPV in the importing country.

The objective of the CAE is thus to professionalize and develop exports on a long-term basis while improving the quality of mangoes, by proposing integrated pest control methods for dealing with the Tephritidae, actions which are both effective and economical, and which Malian planters are able to afford.

It is patently clear that a good knowledge of the biology and behaviour of the fruit-fly species responsible for the damage is an indispensable requirement for successfully setting up and perfecting integrated pest control methods against the Tephritidae associated with the mango tree.

2.2. OBJECTIVES :

For this reason, the main objectives of our study are as follows :

- To establish an inventory of the Tephritidae species responsible for the damage to fruits ;

- To set up a monitoring and alert system for fruit-fly populations in the orchards of the main regions where mangoes are produced for export (Sikasso, Bougouni and Bamako) ;

- To monitor the trend in attack rate of the fruits ;

- To try out spot treatments on mango-tree foliage ;

- To provide a training program for the different players of the subsector, from upstream to downstream, i.e. from the producers down to the exporters.

PART THREE : MATERIALS AND METHODS

3.1. - INVENTORY OF THE TEPHRITIDAE ASSOCIATED WITH THE MANGO TREE :

The fruits pierced by fruit flies were systematically harvested (in non-treated orchards) during the various investigations and taken to the laboratory for weighing, counting, and classification according to variety, date and locale; after being assigned a serial number, they were placed under observation on wire mesh supports resting on basins, so as to allow the larvae to fall easily into the damp sand, and metamorphose there into pupae. Each batch was characterized for a variety on the basis of a site and a date, in order to retain perfect clarity in the traceability of the collections. The breeding took place in a large outdoor insectarium.

Once a week, the sand covering the bottom of the containers was washed and then sieved in order to collect the week's pupae. The pupae, lifted out with soft tweezers, were then arranged in little breeding boxes lined with dampened blotting paper marked with their serial number.

Every 3 or 4 days the hatching were monitored and the adults were lifted out and identified with the aid of a binocular magnifying glass. Insects which could not be identified with certainty needed to be prepared on tinsel or polypore in order to reveal certain morphological differentiation criteria.

3.2. SETTING UP A TRAPPING SYSTEM :

For each of the 3 sites studied, a total of 60 traps was installed in the first week of June (as soon as they had cleared Customs). These 60 traps were divided into 36 dry traps containing sexual attractants (parapheromones) and 24 liquid traps containing food attractants (protein hydrolysate). The use of the two different attractants was necessary to enable the capture of both sexes, the males essentially being drawn by the parapheromones and the females, by contrast, by the protein-based liquids. Our different repetitions formed 4 blocks of 9 dry traps each, and 4 blocks of 6 liquid traps each.

The dry traps comprised :

- 12 terpinyl acetate traps
- 12 trimedlure traps
- 6 methyl eugenol traps
- 6 cuelure traps.

The liquid traps comprised :

- 12 buminal + water traps
- 12 buminal + water + borax traps.

The suggested average density was 6 traps per hectare for the parapheromone traps, with, as a consequence, a distance of approximately 40 meters between traps to avoid any interaction between the attractants. Furthermore, there was a density of 12 food attractant traps per hectare with a distance of approx. 20 meters between traps.

During this harvest, the traps were suspended from a solid branch on the lower third of the foliage at an average distance from the center of the tree. The traps were not allowed to be in direct sunlight ; likewise, we had to take care to leave the different entrances to the traps completely clear.

Moreover, it was imperative to grease the supporting branch (from which the trap hung) with solid fat in order to prevent any predatory activity on the part of ants (Oecophyllae) vis à vis adult Tephritidae which were either dead or waiting in the trap.

Traps were checked on a weekly basis for Waibera (outskirts of Sikasso), Madina (outskirts of Bougouni) and Konyini (outskirts of Bamako).

3.3. MONITORING OF THE TREND IN ATTACK RATE :

In the 3 sites being monitored, we sampled 30 fruits per week / tree / site / variety. We limited ourselves to sampling 4 varieties of commercial interest (Amélie, Kent, Keitt, Brooks). Ten trees per week / site / variety were chosen at random, which gave us a maximum number of 300 fruits per week / site / variety.
A visual check was made of all the fruits, and we proceeded to dissect the fruits which had been pierced, or looked as if they might have been.

3.4. SPOT TREATMENTS :

One of the main objectives of this study is to set up an effective pest control method which producers can afford, and which would avoid any risk of contaminating the mangoes with residues of active materials. The goal would be to keep the populations of the most prolific and most harmful fruit fly species below the economic damage threshold. In Mali, no previous private study has been carried out on this threshold of intervention, and we have not defined it ourselves, since we began our work during the harvest. We have chosen to observe the same threshold used in Réunion for mango and citrus orchards, which is 25 fruit flies per trap per week (Quilici, 1992 ; Vincenot, 1993). It should be mentioned that this threshold applies in Reunion conditions to *C. rosa* and *C. capitata*. In Mali, only the first of these species, the Natal fruit fly, causes sizeable but late damage to mangoes.

Spot treatments were carried out in the same manner in the 3 orchards. A 16-liter Matabi super Agro manual spray was used to spread a mixture containing per 10 liters of water :
- 100 ml of Sumithion L-50 (Sumitomo Chemical Cpy Japan) : 500 g. MA / L.
- 200 ml of 75% protein hydrolysate (Agrisense BCS, Pontypridd, U.K.).

All the rows of a plot of land were treated, but with the variant that only one tree in every two was sprayed. It is important to stress that only the foliage was treated, over a surface area of approx. 1m², at a grown man's height and until runoff.
In Madina we selected a large control plot, free from both spot treatments and traps, so as to able to evaluate the real impact of our actions.

3.5. PROGRESS OF THE TRAINING PROGRAM :

We chose about ten villages around Sikasso, around which to carry out our research. A part from the presence of numerous orchards, the reasons leading to this choice were the strong motivation on the part of the planters in these villages to improve not only the quality of their fruit, but also the agrotechnics of their mango trees, as well as an obvious desire to follow the recommendations put forward.

In general, we relied on the interpreting skills of the Branch Head of the CAE in Sikasso, Mr Cheikh Soumaré, or those of our driver, Mr Issa Cissé.

Before each intervention and around each village, we collected different fruits harboring eggs or corresponding to different stages of degradation of the pulp by the larvae in order to illustrate the damage in relation to the biology of the fruit flies of this family. In so far as was possible, the varieties exposed were four in number : Amélie, Kent, Keitt and Brooks.

In addition, we captured some adult ceratites to enable planters to identify them in the field.

The total length of each training session was 3 hours (1 hour in the field, and 2 hours of presentation and discussion).

The format of each presentation followed the following guidelines :

- introduction of the CAE and the contributors,
- introduction of the main pests and diseases of the mango tree,
- economic importance of fruit flies,
- survey of fruit fly biology and behavior,
- control methods proposed under the heading of integrated pest management,
- importance of trapping and spot treatments,
- short - and medium - term prospects.

In the course of each presentation, we introduced participants in turn to the eggs, larvae and adults of the fruit fly, as well as to the different stages (external and internal) of degradation of the 4 varieties of fruits.

We defined the purpose of our (timely) action, and the goal of succeeding in controlling this pest in the medium term via a set of different control measures grouped together under the heading of integrated pest management. We stressed that our intervention was targeted at trapping (fruit fly) adults and spot treatment of the foliage. Nevertheless, we recommended and insisted on the importance of simple mechanical control measures such as the sanitary harvest and burying (or better yet, incineration) of the fruits which had been pierced. In addition, we advocated that the grafting-on of late varieties which are highly attractive to the fruit flies (Brooks, etc.) be replaced by the grafting-on of varieties which are earlier and/or more attractive in commercial terms (Irwin, Kent).

3.6. EXPERIMENTAL SITES :

The experimental sites chosen in the case of Waibera, Madina and Konyini were selected after several weeks of preliminary visits to and investigations of more than fifty-odd villages around Bamako, Bougouni and Sikasso, during the month of April.

The prerequisites informing this choice were various :

- First of all, the orchard had to produce over 75% mid-season or late exportable varieties such as Kent or Keitt, to enable the sustained monitoring of fruit fly infestations.

- The minimum area for each site then had to be eight hectares, the optimum being in Madina with about twenty hectares, which was more than large enough also to include a control plot, free from trapping and spot treatments. Ten hectares is therefore the minimum for including the trapping repetitions and a control plot. If it is necessary to make do with eight hectares, a neighbouring orchard must be found with similar varieties of fruit to serve as a control.

- Finally, the planter undertook not to subject his orchard, or the immediate vicinity for that matter, to any chemical treatment, so as to avoid any impact on the experiments underway.

- In addition, we tried to target orchards whose planting conditions, regular spacing, fully identified varieties and homogeneous age allowed us to see our experiments through rigorously and under optimum conditions.

PART FOUR : RESULTS AND DISCUSSION

4.1. INVENTORY OF TEPHRITIDAE CLOSELY ASSOCIATED WITH THE MANGO TREE :

A total of 1226 pierced fruits was collected from 15 different sites (**Appendix 2**) over the 6-month consultation period. These 1226 fruits belonged to 15 different varieties of mango which, listed in descending order of harvest size, were as follows :

- Keitt
- Kent
- Brooks
- Amélie
- Smith
- Palmer
- Haden
- Miami late
- Zill
- Julie
- Edwards
- Alfonse de Goa
- Davis Haden
- Eldon
- Bewerly.

The first five varieties were the most numerous ones in the villages around which we carried out our study. Amélie, an early variety, is only in 4th position with 116 fruits, which is hardly surprising since we began these investigations once the harvest was already underway.

From these 1226 fruits, we extracted 13,171 Diptera Tephritidae pupae belonging to 6 different species :

- *Ceratitis cosyra* (Walker)
- *Ceratitis silvestrii* Bezzi
- *Ceratitis quinaria* (Bezzi)
- *Ceratitis rosa* Karsch
- *Ceratitis anonae* Graham
- *Ceratitis ditissima* (Munro).

Identification of the different species was carried out by us, and was verified (in the case of certain species) by Dr M. De Meyer of the "Royal Museum" for Central Africa in Tervuren (Belgium).

Figure 3 shows that 85.58% of the total numbers consist of *C. cosyra*, also known quite rightly as the "mango fruit fly", 7.28% of *C. silvestrii*, 4.89% of *C. quinaria*, 1.80% of *C. rosa* or the "Natal fruit fly", 0.24 % of *C. ditissima*, and finally, 0.21% of *C. anonae*.

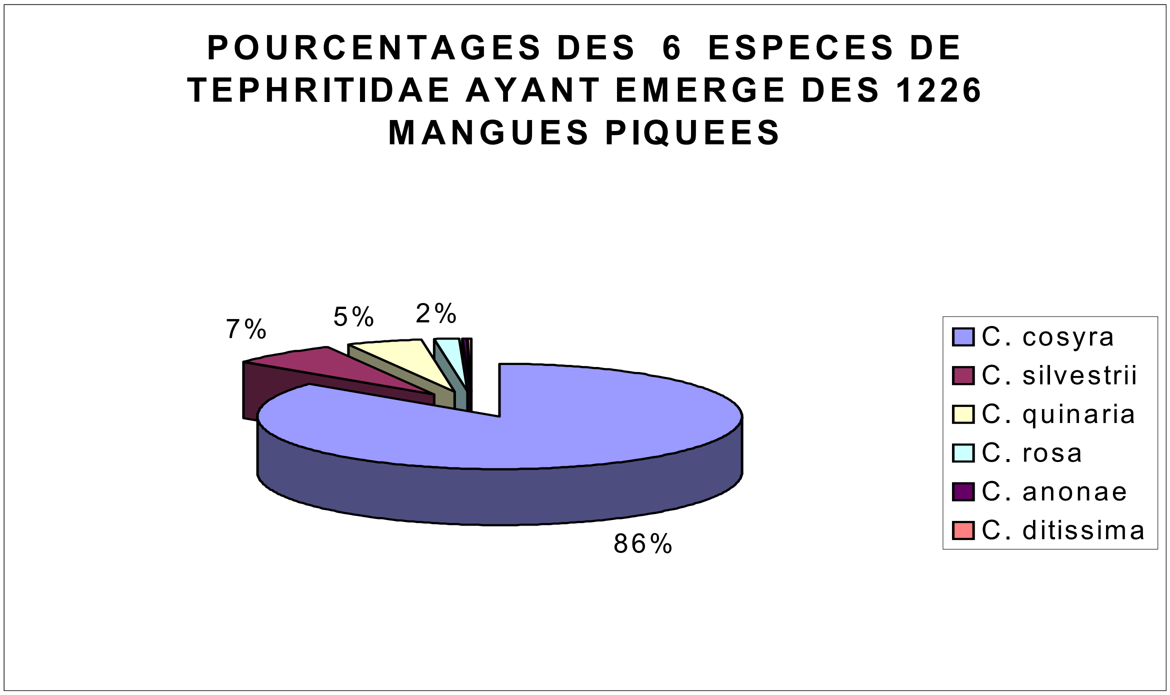


Figure 3 :
PERCENTAGES OF THE 6 TEPHRITIDAE SPECIES EMERGING FROM THE 1226 PIERCED MANGOES

4.1.1.**Inventory of the species according to geographic zone** :

- If we classify according to the zone under investigation, we note that in the Sikasso zone (**Appendix 3**) we harvested 652 fruits from which we extracted 8168 Tephritidae pupae.

In the Sikasso zone, numbers of *C. cosyra* [have been supplanted by] *C. silvestrii* et *C. quinaria* essentially present in April and the beginning of May. According to De Meyer (pers. comm.), the two latter species are in fact closely associated with arid zones, and it is scarcely surprising to see them develop here at the end of a dry season. It is interesting to point out that this is the first time that *C. quinaria* has been found in West Africa, according to Dr De Meyer. Other sightings of this species stem from Bostwana, Namibia and South Africa.

- In the Bougouni zone (**Appendix 4**), we harvested 388 fruits, from which we extracted 2622 Tephritidae pupae.

C. cosyra is still well in the lead here, followed in second place by *C. rosa* with nearly 7% of the total numbers in this zone. According to Dr De Meyer, the latter species actually belongs to the species *C. fasciventris*, which he claims is different from *C. rosa*. In so far as there has been no new description, we shall keep the name of *C. rosa* for this species, which is extremely prolific during the wet season, and which we found in great numbers in Côte d'Ivoire and Guinea (Vayssières, 2000).

- In the Bamako zone (**Appendix 5**) we harvested 186 fruits from which we extracted 2381 Tephritidae pupae.

C. cosyra is still largely dominant there, followed by *C. rosa* in second place.

4.1.2**. Inventory of species according to mango variety** :

A summary of the fruit fly species thus bred in respect of the main (export) varieties found was made by us :

For the variety Amélie, **Appendix 6** shows a preponderance of *C. cosyra* with 83.2 % of the total, followed by *C. silvestrii* with 12.4 % and *C. quinaria* with 4.4 %. We obtained an average of 15 pupae per kg of pierced fruit for the variety Amélie.

For the variety Kent, **Appendix 7** shows a rather lower preponderance of *C. cosyra* with only 57.3 % of the total, followed by *C. silvestrii* (22.4 %), *C. quinaria* (19.2 %), *C. rosa* (0.7 %) and *C. anonae* (0.4 %).
We obtained an average of 18 pupae per kg of pierced fruit for the variety Kent.

For the variety Keitt, **Appendix 8** shows a preponderance of *C. cosyra* with 93.4 % of the total, followed by *C. rosa* (4.2 %), *C. silvestrii* (1.1 %), *C. ditissima* (0.8 %), *C. anonae* (0.4 %) and *C. quinaria* (0.1 %).
We obtained an average of 16 pupae per kg of pierced fruit for the variety Keitt.

For the variety Brooks, **Appendix 9** shows a rather lower preponderance of *C. cosyra* with only 81.2 % of the total, followed by *C. silvestrii* (11 %), *C. quinaria* (6.7 %) and *C. rosa* (1.1 %).
We obtained an average of 45 pupae per kg of pierced fruit for the variety Brooks.

For the variety Smith, **Appendix 10** shows a preponderance of *C. cosyra* with 98.5% of the total, followed by *C. silvestrii* (1.2 %) and *C. rosa* (0.3 %).
We obtained an average of 57 pupae per kg of pierced fruit for the variety Smith.

We note the greater attractiveness of the two latter varieties for the Tephritidae, which has already been observed in Kankan in Guinea (Vayssières, 1995).

4.1.3. <u>Economic importance of the different species</u> :

- ***C. cosyra*** : The adult varies in size (3.34 - 5.40 mm), with wide yellow bands on its wings. The antennae are orangey yellow. The scutellum, white on its basal part and yellow on its apical part (De Meyer, 1998), bears three black spots on its apical part; it also presents two small brown spots on its basal part. The mesonotum, pale with a slight orangish tint, has spots varying in size as well as coloring (De Meyer, 1998) (**Figure 4**).

  C. cosyra is a major pest of the mango in Africa : in South Africa, Kenya, Malawi, Mozambique, Sudan, Tanzania, Zaire, Zambia, Zimbabwe (White & Elson-Harris, 1992), Cameroon (Nonveiller, 1984), Madagascar (Hancock, 1984), Côte d'Ivoire (N'Guetta, 1994 ; Barbet, 2000), Guinea (Vayssières, 2000) and probably in numerous other West African countries.

Besides the mango tree (*Mangifera indica* L.), this pest also attacks the guava (*Psidium guajava* L.), the Seville orange (*Citrus aurantium* L.), the avocado (*Persea americana* P. Miller), the wild custard apple (*Annona senegalensis* Pers.), and numerous other cultivated and wild fruit trees (Hancock, 1987 ; White & Elson-Harris, 1992 ; De Meyer, 1998). It was also reported in Mali (Noussourou & Diarra, 1995) on cultivated fruit trees such as the tangerine (*Citrus reticulata*), the orange tree (*Citrus sinensis*) and on wild fruit trees such as the shea nut tree (*Butyrospermum parkii*), the African peach tree (*Nauclea latifolia*), and a liana (*Landolphia senegalensis*).

This species is therefore a formidable pest, due both to the multiplicity of its host plants wild and cultivated, its wide geographical distribution on the African continent, and its precocity, found as it is at the very outset of the harvest in Mali (Noussourou & Diarra, 1995) Côte d'Ivoire (N'Guetta, 1998) and Guinea (Vayssières, 2000), to mention West Africa alone.

- ***C. silvestrii*** : The adult is generally smaller (3.75 - 4.00 mm) and has yellow antennae. The scutellum is white on its basal part and yellow on its apical part (De Meyer, 1998) ; it has three very distinct black spots on its apical part, without small brown spots on its basal part. The mesonotum is white (**Figure 5 g**) with just two lateral black spots starting at the transverse suture. The postpronotum is white without a black spot.

This species is found in Nigeria and Senegal (Silvestri, 1913). According to De Meyer (1998), it lives in wild fruit trees such as *Chrysobalanus* sp and *Vitellaria paradoxa*, and the mango tree (*M. indica* L.) is a host not yet recorded. *C. silvestrii* is a major pest, occupying second place with over 7% of the total behind *C. cosyra* and being relatively precocious as well.
It would be interesting to begin harvesting the pierced mangoes even earlier (in February – March), in order to determine its ecological niche in relation to that of the previous species.

- ***C. quinaria*** : The adult is variable in size (3.60 – 4.75 mm), with yellow-to-orangey-yellow antennae. The scutellum is white on its basal part and yellow on its apical part (De Meyer, 1998) ; it has five black spots, three on its apical part and two small ones on its subapical part. The mesonotum, which is pale in color, has no truly visible spots. (**Figure 5 h**).

  C. quinaria is distributed in Africa throughout South Africa, Botswana, Malawi, Namibia, Sudan and Zimbabwe (White & Elson-Harris, 1992).

It is a potential pest of cultivated and wild fruit trees (White & Elson-Harris, 1992) of the dry African savannas. According to De Meyer (pers. comm.) this is the first mention of both the mango tree (*M. indica* L.), a host not yet recorded, and West Africa. It would be interesting to study this species, like the previous one, in February – March, and in several regions of Mali, in order to define their host-plant ranges, their phenologies, and their precise impacts as pests of the mango tree, with respect to *C. cosyra*.

These three species are therefore major pests of the mango tree, both because of their considerable numbers, and because they attack varieties of commercial interest (Amélie, Kent, etc.) at the beginning of the harvest.

- ***C. rosa*** : The adult is variable in size (4.5 - 6 mm), with wide brown bands on its wings. The scutellum is divided into three black zones by characteristic white or yellow bands.

  C. rosa is distributed in Africa throughout South Africa, Angola, Ethiopia, Kenya, Malawi, Mozambique, Nigeria, Uganda, Rwanda, Swaziland, Tanzania, Zaire, Zambia, Zimbabwe (White & Elson-Harris, 1992), Cameroon (Nonveiller, 1984), Côte d'Ivoire (N'Guetta, 1994 ; Barbet, 2000), Guinea (Vayssières, 2000) and probably in numerous other West African countries.

This species is a major pest of some fifty cultivated and wild fruit trees in Africa (White & Elson-Harris, 1992), including the mango tree, as in the Mascarene Islands and on Réunion in particular (Etienne, 1982 ; Quilici, unpublished). It is of relatively minor quantitative importance until June, and chiefly from July and August in terms of the pierced fruit placed under observation. As we shall see in the following chapter, the trapping results complement these observations of the pierced fruits.

- ***C. anonae*** : This species is akin to the previous one, but distinguished from it in the case of the male by combs with particularly long black bristles on its tibia and median femur.

  C. anonae is widespread throughout Africa, in Cameroon, the Congo, Côte d'Ivoire, Ghana, Nigeria, Uganda, Tanzania, Togo and Zaire (White & Elson-Harris, 1992).

This species is a major pest of ten or so cultivated and wild fruit trees in Africa (White & Elson-Harris, 1992) including the mango. It only really appeared, in the case of the pierced fruits placed under observation, from June onwards, chiefly in July and in relatively low numbers. It would seem to be slightly more precocious than *C. rosa*, and its actual economic importance is difficult to determine exactly in Mali. According to Vayssières (2000), this species poses more of a threat as a pest of the mango in the wetter Sudanian zones (in Guinea) than in the Sahelian zones.

- ***C. ditissima*** : The mesonotum of the males of this species bears a sickle-shaped brown spot covering its entire anterior width. The females have dark bristles on the lower half of their anepisternum, and a lighter pilosity on the upper part.

  It is also said to be a species of secondary importance on the mango tree, like *C. anonae,* at least in Mali.

The exact distribution of *C. ditissima* on the African continent is not known with certainty, particularly since it has possibly been confused with *C. punctata*.
We should point out that the species identified as *P. punctata* by Mssrs Noussourou and Diarra (1995) is in fact quite probably *C. ditissima*, as the two species are indeed very closely related.

4.1.4. Breeding of parasitoids :

We obtained the following larval-pupal parasitoids essentially from the “mango fruit fly” *C. cosyra*, and also to a lesser extent from *C. rosa* :

- *Psyttalia perproximus* (Silvestri)………………..Braconidae, Opiinae
- *Psyttalia cosyrae* (Wilkinson)………………….. Braconidae, Opiinae
- *Fopius caudatus* (Szépligeti)…………………….Braconidae, Opiinae
- *Diachasmimorpha fullawayi* (Silvestri)…………Braconidae, Opiinae
- *Tetrastichus giffardianus* Silvestri ……………...Eulophidae, Tetrastichinae
- *Spalangia simplex* Perkins………………………Pteromalidae, Pteromalinae
- *Pachycrepoideus vindemmiae* (Rondani)………. Pteromalidae, Pteromalinae
- *Leptopilina victoriae* Nordlander ……………….Figitidae, Eucoilinae
- *Leptopilina aff. fimbriata* (Kieffer)………………Figitidae, Eucoilinae
- *Asobara sp*……………………………………….Braconidae, Alysiinae.

This inventory may seem significant bearing in mind the size of the fruit fly populations, but the factors governing host-parasitoid relations are in fact very poorly understood. If one wished to strengthen the action of the natural control agents, the first step would be to study these relations.
On the other hand, it should be stressed that the latter four species can also live off of the larvae and pupae of Drosophilidae dipteras.

4.2. MONITORING OF THE TRAPPING SYSTEM :

4.2.1. Total numbers captured for the 3 sites :

The total numbers captured for each species and for the 17 consecutive weeks of trapping are given in **Table 1** (below).

Table 1 :

TOTAL NUMBERS OF TEPHRITIDAE CAPTURED BY TRAPPING ON 3 SITES IN MALI OVER 17 CONSECUTIVE WEEKS (from 06/12/00 to 10/02/00)								
	Waibera	%	Madina	%	Konyini	%	*TOTALS*	%
C.cosyra	24131	93.94	54224	90.82	41921	96.14	**120276**	93.24
C. silvestrii	697	2.71	317	0.53	623	1.43	**1637**	1.27
C. quinaria	186	0.72	133	0.22	25	0.06	**344**	0.27
C. rosa	399	1.55	4232	7.09	74	0.17	**4705**	3.65
C. anonae	24	0.09	244	0.41	3	0.01	**271**	0.21
C. capitata	14	0.05	11	0.02	6	0.01	**31**	0.02
C. ditissima	4	0.02	37	0.06	0	0.00	**41**	0.03
C. bremii	59	0.23	97	0.16	106	0.24	**262**	0.20
B. cucurbitae	4	0.02	190	0.32	840	1.93	**1034**	0.80
D. ciliatus	7	0.03	10	0.02	1	0.00	**18**	0.01
D. punctatifrons	121	0.47	47	0.08	1	0.00	**169**	0.13
D. bivittatus	36	0.14	149	0.25	5	0.01	**190**	0.15
D. vertebratus	5	0.02	15	0.03	0	0.00	**20**	0.02
TOTALS	25687		59706		43605		128998	

With the aid of these 180 traps, we captured a total of 128,998 adult Tephritidae belonging to 13 different species ; the 6 species of fruit flies closely associated with the mango tree represent nearly 99 % of this figure.

C. cosyra remains the predominant species on the 3 sites, at over 90%. In the Sikasso and Bamako zones, *C. silvestrii* is in second place, while it is *C. rosa* in the Bougouni zone.

C. capitata is a Mediterranean fruit fly (medfly) which we raised essentially on citrus fruits in Mali, although it may attack mangoes ; moreover, we obtained it from mangoes in Guinea (Vayssières, 2000) just as we did with *C. bremii*. *C. capitata* larvae are also found in chiles and bell peppers (Solanaceae).

B. cucurbitae, *D. ciliatus*, *D. punctatifrons*, *D. bivittatus* and *D. vertebratus* are Tephritidae fruit flies of the tribe Dacini which are essentially closely associated with the vegetables and fruits of the family Cucurbitaceae. Nevertheless, our colleagues in Korhogo obtained small numbers of *D. bivittatus* from mangoes (N'Guetta, 1998 ; Barbet, 2000).
It is the first recording in Mali of *B. cucurbitae*, a formidable pest of the Cucurbitaceae in Asia, in the Pacific, on Réunion (Vayssières, 1999), and present in East Africa (White & Elson-Harris, 1992).

4.2.2. <u>Total numbers captured for Waibera</u> :

Appendix 11 sets out in detail the weekly captures based on the attractants used.
Here, we confirmed what we had noted when the pierced fruits were placed under observation :

- *C. silvestrii* and *C. quinaria* are precocious dry-season species trapped during the first few weeks, then disappearing in Waibera and Madina.
- *C. cosyra* is a species present throughout the entire harvest both during the dry season and the wet season on all 3 sites.
- *C. rosa*, *C. anonae* and *C. ditissima* are species present at the end of the harvest, essentially during the wet season in July and August in Waibera and Madina.

4.2.3. <u>Total numbers captured for Madina</u> :

Appendix 12 sets out in detail the weekly captures based on the attractants used.

We can observe the same order in the appearance of the species, although with a slight delay. The *C. rosa* population, for example, peaks at the end of August – beginning of September.

4.2.4. <u>Total numbers captured for Konyini</u> :

Appendix 13 sets out in detail the weekly captures based on the attractants used.

The drier climatic conditions (little rain in June and July) of the Bamako zone allowed a spreading out of the *C. silvestrii* and *C. quinaria* captures over the entire harvest. Consequently, the Natal fruit fly, *C. rosa*, was only captured sporadically.

4.2.5. <u>Summary of the species captured according to attractant type</u> :

Unlike the food attractants based on protein hydrolysate (buminal), the sexual attractants or parapheromones only capture Tephritidae males (with the exception of terpinyl acetate).

- **Trimedlure :** This parapheromone essentially attracts the males of *C. rosa*, *C. capitata* and *C. anonae*. It is not unknown for us to capture a few *C. cosyra* males in Madina with this attractant, but this remains an exception.

Although terpinyl also captures *C. rosa*, trimedlure remains without a doubt the best attractant for the Natal fruit fly.
Moreover, out of a sample taken by us of 650 adult *C. rosa*, 99% were males (in Madina).

- **Terpinyl acetate :** This parapheromone is both a relatively effective attractant and a versatile one, suitable for capturing *C. cosyra*, *C. silvestrii*, *C. quinaria, C. rosa*, *C. anonae,* and even *C. ditissima.*

It is the only high-performance attractant capable of capturing the males of the 3 precocious species in Mali, *C. cosyra*, *C. silvestrii* and *C. quinaria.*
It is of more than passing interest to note that terpinyl acetate also captures *C. rosa* females, and that out of a sample of 550 adults captured with this attractant (in Madina), we had 23% females (as against 77% males).

- **Methyl eugenol :** This parapheromone is the only attractant which captured *C. bremii* males, although it also caught a few *C. rosa* on several occasions (Madina).

- **Cuelure :** This parapheromone captures *B. cucurbitae*, *D. ciliatus*, *D. punctatifrons*, *D. bivittatus* and *D. vertebratus* males.

- **Buminal :** Buminal alone is much less effective than the following attractant, essentially enabling the capture of *C. cosyra*, and sometimes *C. rosa* (Madina).

Buminal alone enables the capture of 85% females for *C. cosyra* and 70% females for *C. rosa*. These results were obtained from a sampling of 600 fruit flies captured with buminal alone, for the 3 sites combined.

- **Buminal + borax :** The mixture of buminal and borax enables the capture of *C. cosyra*, *C. silvestrii*, *C. quinaria* and *C. rosa*. The acidity of the mixture, owing to the borax, makes it more attractive to the fruit flies.

The mixture of buminal and borax enables the capture of 85% females for *C. cosyra* and 71% females for *C. rosa*. These results were obtained from a sampling of 600 fruit flies captured with buminal + borax, for the 3 sites combined.

4.3. MONITORING THE TREND IN ATTACK RATE :

4.3.1. Plots laid with traps and treated :

The results are presented in the form of the following tables (Tables 2 – 5) based on the site, the date of the observations, and the main varieties still present in the plantations :

Tables 2 – 5 : ESTIMATE OF DAMAGE FOR THE 4 VARIETIES (plots laid with traps and treated).

Var. KENT	Waibera (Sikasso)	Madina (Bougouni)	Konyini (Bamako)
from 06/12 to 06/15	47 %	19 %	29 %
from 06/19 to 06/22	44 %	25 %	37.5 %
from 06/26 to 06/29	28 %	34.5 %	
from 07/03 to 07/06		31.5 %	
from 07/10 to 07/13		28 %	
from 07/17 to 07/20		24 %	
from 07/24 to 07/27		20 %	
from 07/31 to 08/03		14 %	
from 08/07 to 08/10		16.8 %	

Var. KEITT	Waibera (Sikasso)	Madina (Bougouni)	Konyini (Bamako)
from 06/12 to 06/15	38 %	39 %	38 %
from 06/19 to 06/22	39 %	35 %	39 %
from 06/26 to 06/29	41 %	49.5%	26 %
from 07/03 to 07/06	27.5 %	41 %	
from 07/10 to 07/13	24.5 %	28.6 %	
from 07/17 to 07/20	14.6 %	23.3 %	
from 07/24 to 07/27	15 %	15.6 %	
from 07/31 to 08/03	10.3 %	9.3 %	
from 08/07 to 08/10	8.3 %	10 %	

Var. BROOKS	Waibera (Sikasso)	Madina (Bougouni)	Konyini (Bamako)
from 06/12 to 06/15	36 %		
from 06/19 to 06/22	38.5 %		
from 06/26 to 06/29	62 %		87 %
from 07/03 to 07/06	38.5 %		
from 07/10 to 07/13	32 %		
from 07/17 to 07/20	22.6 %		
from 07/24 to 07/27	21 %		
from 07/31 to 08/03	15.3 %		
from 08/07 to 08/10	14		

Var. HADEN	Waibera (Sikasso)	Madina (Bougouni)	Konyini (Bamako)
from 06/12 to 06/15			48 %
from 06/19 to 06/22			40 %
from 06/26 to 06/29			42 %
from 07/03 to 07/06			

- On the Waîbera site, the Kent variety suffered the most depreciation from Tephritidae attacks during the first 2 weeks. During the third and fourth week, it was the Brooks variety which bore the brunt of the damage inflicted by fruit flies. The absence of a result for Kent at the beginning of July is due to the fact that the last fruits had been harvested. The brunt of damage to fruits was located on the lower stratum of the tree over the first two meters, particularly for Keitt. Fruits which were shaded and surrounded by foliage were particularly affected. Damage then decreased on a regular basis in July and August.

- On the Madina site, the Keitt variety proved more attractive to the fruit flies than Kent. This might possibly be explained by the pedologic influence on the coloring of the fruit ; in fact, unlike the lateritic substrata, this clayey-sandy soil does not allow a vivid coloring of Kent and Keitt ; the Keitt specimens retain a yellow coloring here, which seems to be particularly attractive for the medflies. Other factors must also play a part. The majority of the attacks there still affect fruits on the lower stratum, particularly in the case of Keitt. From mid July onwards, the damage then decreases regularly in July and August.

- On the Konyini site, it is the Haden variety which suffered the most damage on average. The very high percentage of attacks on Brooks must be taken with a grain of salt, since the counts were made on a single tree. Harvests were also underway at the end of June.

4.3.2. Untreated plot without traps :

In the following tables (6 and 7), we have set out the results of the damage to the Kent and Keitt varieties in Madina, but in this case on “control” plots (i.e. those without traps or spot treatments).

Tables 6 and 7 : ESTIMATE OF DAMAGE FOR THE 2 VARIETIES (untreated plot)

Var. KENT		Madina (Bougouni)
from 07/10 to 07/13		48 %
from 07/17 to 07/21		42 %
from 07/24 to 07/27		35.3 %
from 07/31 to 08/03		29.3 %
from 08/07 to 08/10		35.3 %

Var. KEITT		Madina (Bougouni)
from 07/10 to 07/13		42 %
from 07/17 to 07/21		39 %
from 07/24 to 07/27		35.6 %
from 07/31 to 08/03		28.3 %
from 08/07 to 08/10		36.6 %

The results for treated plots (Tables 2 and 3) and control plots (Tables 6 and 7) are significantly different, and highlight the importance of the pest-control measures implemented.

In other untreated orchards (visited in April), we recorded from 26 – 61% damage to fruits for the Amélie variety.

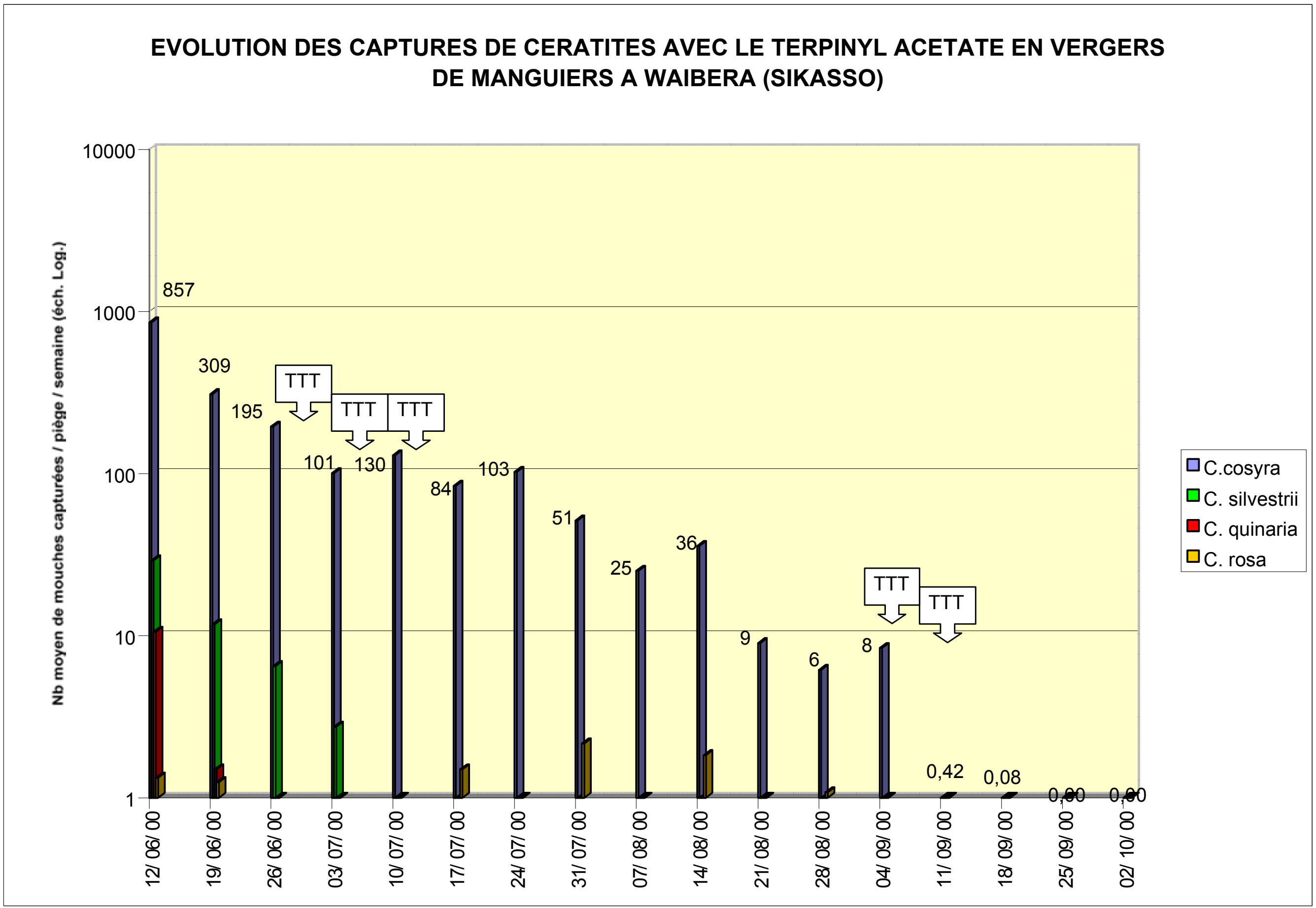
4.4. SPOT TREATMENTS :

We were only waiting for one authorization (USAID's) to begin the spot treatments, the economic damage thresholds in terms of the trap readings having of course been completely exceeded from the first few weeks.

4.4.1. Waibera site :

The first series of treatments was carried out (**Figure 6**) in the last week of June (06/26), the second during the first week of July (07/03), the third during the second week of July (07/10), and the fourth and fifth during the first and second weeks of September (09/04 and 09/11, respectively).

Figure 6 :



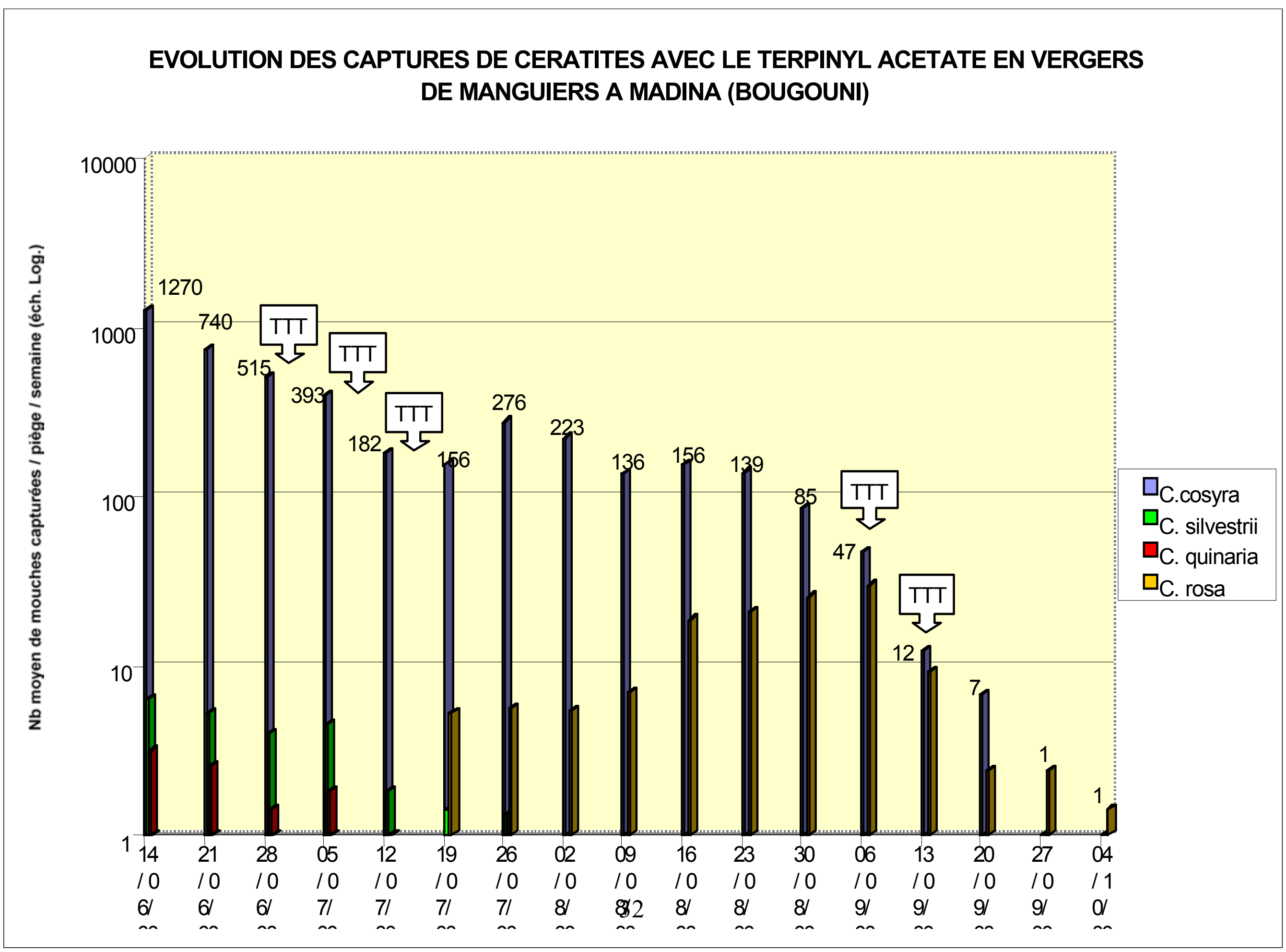
[Vertical caption to left of chart:] Average number of fruit flies captured / trap/ week (Log. Scale)

In Waibera (**Figure 6**), the first treatment caused a 50% drop in one week in the average number of *C. cosyra* captured per trap.
The second treatment was ineffective, with an increase from an average of 101 *C. cosyra* captured per trap to 132. This can be explained by rainfall on the evening of the treatment itself as well as all the following day, which washed away the spray which had been applied.
The third treatment achieved a drop from an average of 130 *C. cosyra* captured per trap to 84. The moderate effectiveness of this treatment is once again due to rain on the days following the spraying.
The fourth (09/04) and fifth (09/11), by contrast, were successful in wiping out the residual populations of *C. cosyra* as well as those of other species.
Within the same time period, this achieved a 75% reduction in the *C. rosa* populations existing at the end of August, bearing in mind that there were still scattered Keitt and Brooks fruits up until the third week of September.

4.4.2. Madina site :

The first series of treatments was carried out (**Figure 7**) in the last week of June (06/28), the second during the first week of July (07/05), the third during the second week of July (07/12), and the fourth and fifth during the first and second weeks of September (09/06 and 09/13, respectively).

Figure 7 :



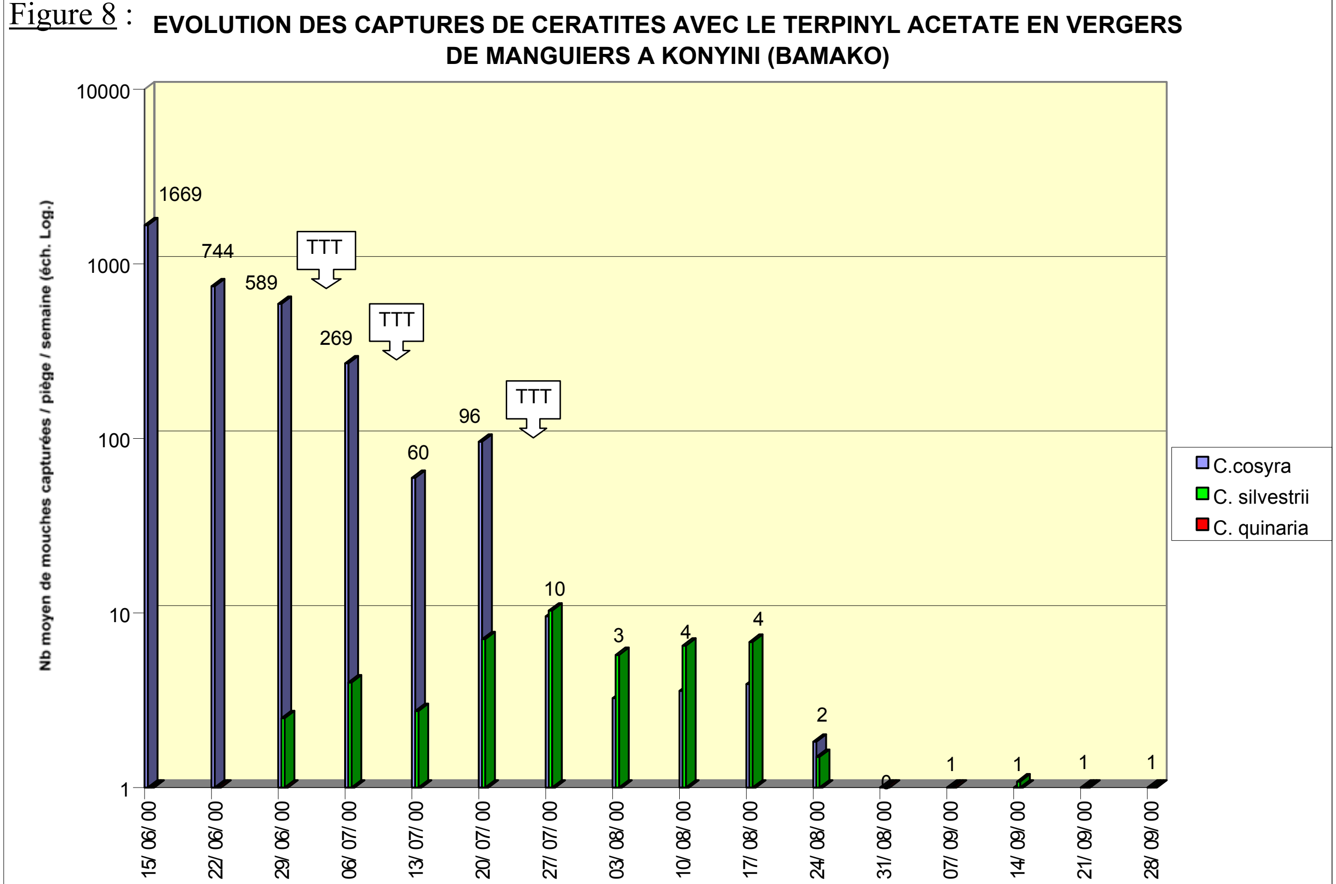
In Madina (**Figure 7**), the first treatment obtained modest results in one week, reducing the average number of *C. cosyra* captured per trap from 515 to 393.
By contrast, the second treatment was more effective, reducing the average number of *C. cosyra* captured per trap from 393 to 182.
The third treatment did not obtain the results expected, with a drop from an average of 182 *C.* cosyra captured per trap to 156. This is explained by rainfall throughout the following day, which caused the belated washing away of the spray which had been applied.
The fourth (09/06) caused a drop below the economic damage threshold, set at 25 fruit flies per trap per week.

The fifth (09/13) consolidated the rapid fall in *C. cosyra* populations, as well as those of other species.
It is particularly interesting to note that the fourth series of treatments caused a drop below the economic damage threshold for both *C. cosyra* and *C. rosa*. In point of fact, we had an average of 47 *C. cosyra* per terpinyl trap, and 39 *C. rosa* per trimedlure trap on 09/06, giving an average of 12 *C. cosyra* per terpinyl trap and 11 *C. rosa* per trimedlure trap on 09/13. If we monitor the *C. rosa* populations trapped with terpinyl rather than with trimedlure, we arrive at the same conclusions. And since we know (cf § 4.1 et 4.2.) that *C. cosyra* and *C. rosa* are the two major species which must be neutralized, the results are encouraging.

4.4.3. Konyini site :

The first series of treatments was carried out (**Figure 8**) during the last week of June (06/29), the second during the first week of July (07/06), the third during the third week of July (07/20).

Figure 8 :



In Konyini (**Figure 8**), the first treatment caused more than a 50% drop in one week of the average number of *C. cosyra* captured per trap, going from an average of 589 to 269 *C. cosyra* captured per trap.
The second was even more effective, with a drop from an average of 269 *C. cosyra* captured per trap to 60. The absence of treatments in mid July allowed *C. cosyra* populations to rise to 96 *C. cosyra* captured per trap.
The third and last treatment brought about a reduction by a factor of 10 in the average number of *C.* cosyra captured per trap, thus placing captures comfortably below the economic damage threshold which we had set at 25.

It is interesting to note the impact of these treatments both in terms of the rates of damage recorded to fruits (on the tree), and the number of fruit flies captured. In point of fact, during the first week of July, the data available for Waibera and Madina indicate a decrease in fruit fly attacks and in the number of captures.
Furthermore, the bad weather conditions (thundery showers) considerably hampered our application of these spot treatments. In fact, we quite obviously called off these treatments when it was raining, as well as when storms threatened. Nevertheless, we were unable to avoid a certain amount of rainfall in the evening or on the night following the spraying, with a consequent stagnation of, indeed, an increase in fruit fly populations the following week.

Once again, we would stress the need to begin the trapping and any spot treatments at the beginning of next year (before the start of the harvest) <u>in order to enable us to really test this pest-control method under the best conditions</u>. In fact, if by applying the treatments <u>very early on</u> – as soon as we are bordering on the threshold of an average of 25 fruit flies per trap per week – we are able to prevent any infestations and the exceeding of the threshold, we would then certainly be able to free ourselves from the weather constraint by spacing out the late treatments and suppressing those which entail a risk of washout.

4.5. PROGRESS OF THE TRAINING PROGRAM :

- On May 30, we arrived in <u>Makandiassa</u>, in accordance with the schedule of the action plan, in order to hold our training session ; Mr I. Cissé officiated as interpreter.

- On June 20, we held our training session in <u>Waibera</u> under the aegis of the village chief, Mr Diafara Diarra, relying on the interpreting skills of the Branch Head of the CAE in Sikasso, Mr Cheikh Soumaré.

- On June 24, we arrived in Farako to hold our training meeting ; Mr I. Cissé officiated as interpreter.

- On July 11, we arrived in <u>Kapala,</u> in accordance with the schedule of the action plan, in order to hold our training session on fruit flies. It was held under the aegis of the village chief, Mr Zana Berté; Mr G. Livingstone and C. Soumaré also attended.

- On July 14, we held our training session in Konyini under the aegis of the village chief, Mr Fama Traoré; Mr S. Bouaré officiated as interpreter.

- On July 17, we held our training session in Sibirasso under the aegis of the village chief, Mr Sékou Traoré; Mr C. Soumaré officiated as interpreter.

- On July 20, we held an awareness-raising meeting on growing techniques and the phytosanitary problems of the mango tree at Nyessoumala in response to a general request relayed by a planter, Mr T. Soumaoro.

- On July 21, we held our training session on fruit flies at Kaî under the aegis of the village chief Mr T. Sogodogo ; Mr C. Soumaré also officiated as interpreter.

- On July 28, we held an awareness-raising meeting with the exporters on the phytosanitary problems of the mango tree in Bamako (CAE meeting room), and more particularly on methods for detecting and controlling fruit flies as well as certain pathogens (stem-end rot) and physiological disorders ("soft nose").

- On August 4, we held our training session on fruit flies in Mandela (postponed meeting) under the aegis of the village chief Mr K. Ballo ; Mr I. Cissé officiated as interpreter.

- On August 5, we held our training session on fruit flies in Loulouni (postponed meeting) under the aegis of the village chief Mr B. Mélégué ; Mr I. Cissé officiated as interpreter. Other problems were broached, in particular the cultural management of citrus as well as mango trees.

- On August 9, we held our training session on fruit flies in Madina (postponed meeting) under the aegis of the village chief ; Mr I. Cissé officiated as interpreter.

Furthermore, numerous planters enquired after the address of our CAE office in Sikasso, some of whom subsequently paid us a visit.

The following table (**Table 8**) summarizes the training sessions we have held during the consultation. We should point out that two of the training sessions were not scheduled in the action plan : the one in Bamako with the Malian exporters and the one in Nyessoumala with the border planters. We felt that it was important to include these in our planning, despite an already very busy work program.

Table 8 : Summary of the training sessions

Place	Date	No. of participants	Results
Makandiassa	05/30	19	Scheduled session held
Waibera	06/20	28	Scheduled session held
Farako	06/24	31	Scheduled session held
Kapala	07/04		Session scheduled and postponed to 07/11
Konyini	06/29		Session scheduled and postponed to 07/14
Kapala	07/11	8	Scheduled session held
Konyini	07/14	22	Scheduled session held
Sibirasso	07/17	15	Scheduled session held
Nyessoumala	07/20	22	Unscheduled session held
Kaî	07/21	17	Scheduled session held
Bamako (CAE)	07/28	12	Unscheduled session held
Mandela	08/04	31	Scheduled session held
Lolouni	08/05	11	Scheduled session held
Madina	08/09	18	Scheduled session held

PART FIVE : RECOMMENDATIONS

5.1. INVENTORY OF THE TEPHRITIDAE CLOSELY ASSOCIATED WITH THE MANGO TREE :

The inventory of the Tephritidae species which are pests of grafted mangoes only really started in mid April in the Sikasso and Bamako zones, and even later, in mid June, in the Bougouni zone.

It is therefore important to fill this gap next year by placing under observation fruits subject to medfly attack from February to June. It is possible that particularly precocious species may have escaped our notice. On the other hand, it would be particularly useful to become better acquainted with the ecological niches of the 3 precocious species which we have highlighted, *C. cosyra*, *C. silvestrii* and *C. quinaria*. A number of practical applications in terms of pest management would follow on from this.

In February, it would be interesting to take a sample harvest of the little mangoes which fall due to natural thinning, and which take on a yellow-orangey color. In fact, we noticed in Guinea (Kankan zone) that these small fruits which fall prematurely may harbor one or two medfly larvae (Vayssières, 1995) of *C. cosyra.* This would allow a species to begin reproducing even before the harvest. This should be checked, however, because the intervention dates in the orchards will not necessarily be the same in this case.

On the other hand, we have not harvested any extra-large mangoes, and therefore do not know which Tephritidae species attack them. It is probably the Tephritidae species which we have obtained from improved (grafted) varieties, but this remains to be proved.

Furthermore, we have made no investigations or collections in terms of wild fruits, despite this being a particularly important area as regards the implementation of a pest management strategy. Numerous wild fruits not only enable the large-scale multiplication of fruit fly populations, but may also facilitate the survival of residual colonies outside of the mango fruiting period (in the dry season).

5.2. SETTING UP A MORE EXTENSIVE TRAPPING SYSTEM :

Thanks to the trapping system set up by us, we were able to capture the fruit-fly species which we had obtained from the mangoes which had been attacked, as well as to test several attractants in order to determine which were the most effective.
Furthermore, any study involving the monitoring of the insect capture trend, and of the Tephritidae capture trend here, must be carried out for several years in a row, so that it can be validated.
Bearing this in mind, and within the context of a new harvest, we recommend the following actions :

- Carry on working with the planters with whom we were involved during the year 2000 harvest, i.e. Mr Soumaîla Diarra in Waibera, Mr Fanto Traoré in Konyini, and Mr Bakary Ballo in Madina ;

- Extend the trapping network by increasing the number of sites involved from 3 to 9 ;

- Set up the traps at the beginning of January in the orchards we have chosen ;

- Install at the same time one thermo-hygrograph and one pluviometer per orchard ;

- Select new orchards in the zones of Niéna, Yanfolila, Nyessoumala and Sélingué for the placement of traps, new sites which will fulfill the same selection criteria as those in Waibera, Madina and Konyini ;

- Bring trapping with terpinyl acetate into general use for parapheromone traps, since this attractant captures the 4 main species of fruit fly closely associated with the mango tree ;

- For liquid attractants, test the new three-component lures (containing putrescine, trimethylamine and ammonium acetate) which are particularly effective in attracting female medflies (Quilici, 2000) : just which species can be trapped in Mali remains to be determined ;

- Also test the empty McPhail traps to use them as color traps only (not forgetting to install the DDVP strip), since we have had good and timely results with these traps utilized as such ;

- Finally, test the photosensitive substances which have yielded mixed results in other countries owing to various sets of problems : as they can replace the insecticides in the spot treatments, these substances deserve to be tested in the Malian context.

5.3. MONITORING THE ATTACK RATE :

We monitored the attack rate for the Florida varieties of fruits during, and especially at the end of the harvest, but this is not enough.

We feel that it is important to monitor the attack rate for the Florida varieties throughout the entire harvest, and in particular at the outset of the harvest, which is an especially crucial time.
Likewise, it would be very useful to monitor the attack rate for fruits of the Amélie variety, as well as for those of other exportable varieties, particularly precocious ones (Irwin, Zill, etc.).

Furthermore, we have not been able to place under observation the fruits attacked within the context of these observations of fruits attacked, due to a lack of manpower and space. It would be of more than passing interest to plan to do so in future actions of this type.

5.4. SPOT TREATMENTS :

Once again we would stress the need to begin the trapping and to be on standby for any possible treatments at the start of next year (before the start of the harvest), so that we can really test this pest control method under the best conditions, and thus ensure better protection of the mangoes of the targeted orchards.

Within the context of these treatments, it would be particularly interesting to vary the number of trees to be tested in a given row : every second tree, every third tree, etc., as well as the amount of buminal used in the composition of the spray. In the case of an identical result, of course, we will tend to prefer the most economical methods of application.

As we have stated previously, it will be necessary to calculate the economic damage thresholds for the Tephritidae during the next harvest based on the population trends for the different species in question, the damage recorded to the fruits, the production costs, and sales – all this for each variety.

It is quite clear that we cannot at present make any recommendation for spot treatments for the next harvest at Malian Agricultural Development Services level, despite the strong demand we have met with to do so. It is imperative that we rigorously pursue these treatments in 2001 in the orchards of the planters with whom we have already worked.

5.5. TRAINING PROGRAM :

It would be particularly opportune to extend this training program to the other zones in which the trapping has been extended. This year’s experience has shown us the necessity of planning village meetings geared to their work programs and other activities.

In the field, practical teaching aids such as fact sheets will be used for preference, with color print reproductions making it possible to distinguish between the species, and showing the damage trend.

Before the harvest and at its outset, we might advantageously hold training sessions for the mango-purchasing agents and exporters in halls, using video aids. These aids would focus on the symptoms of fruit fly attack with respect to different varieties, and their development, both external and internal. The optimum cutting periods for each variety, as well as the preferential strata of the tree will also be favored for the cutting. The fruits of the lower stratum are, in fact, always infested to a greater extent than those of the upper strata.

Likewise, before the harvest and at its outset, we might advantageously hold training sessions, using video aids, for the staff at the packing stations, essentially placing the emphasis on the symptoms of fruit fly attack on Amélie, Kent and Keitt ; we will attempt to illustrate the daily external development of the holes for each of the 3 varieties. Particular stress will be laid on the detection of a few days, or at most a week, old.

5.6. OTHER RECOMMENDATIONS :

While waiting for developments of this type, we still have at our disposal a raft of control measures which might possibly complement the spot treatments advocated, and which should also be promoted to reduce the medly population level below the economic damage threshold. It is particularly important to grasp the concept of complementarity in these different components of integrated pest management, and the importance of implementing them simultaneously at the outset of infestation, without waiting for the fruit fly populations to increase to excessive levels.

Without going into too much detail, we list below the main techniques which can be used :

5.6.1. Short-term technical recommendations :

- The destruction of fruits with holes is a very useful complementary method in any control program aimed at these pests ; the attacked fruits must be picked (or gathered from the ground when they fall) and destroyed as soon as possible before the larvae are able to metamorphose into pupae in the soil. Unfortunately, one all too often sees fruits decomposing under the trees, fruits which serve as a breeding medium for the multiplication of the species. One of the best means of destroying these fruits is to burn them, or to sprinkle them with kerosene, because burial is never 100% reliable, as the larvae have a formidable propensity and ability to rise to the surface.

- Cultural procedures, for example the neutralization of the wild fruits (Annonae, etc.), at least those in the vicinity of the mango orchards.
  The promotion of precocious varieties such as Irwin could also be of definite interest with regard to the dynamics of the fruit fly populations.
  Plowing in any case constitutes a modest aid within the context of an integrated pest management program, with its impact on the timely destruction of the pupae. Moreover, plowing is very important in protecting the orchards from devastating brush fires.

- Finally, biological control could make a by no means insignificant contribution, endeavoring in advance to better grasp the complexity of food chains and the importance of different (biotic and abiotic) factors controlling populations of fruit fly parasitoids. In actual fact, there are numerous parasitoid species found in Mali which could be better exploited.

5.6.2. Various recommendations :

- Cooperation with the IER in terms of the pursuit of our actions is, we feel, of importance within the mango subsector. Mr F. Sanogo, who followed our experiments over two months with interest, should be able to fully guarantee the continuation of these activities in liaison with confirmed entomologists next year.

- The identification and setting up of a Regional Pest Control Project aimed at the Tephritidae of the mango tree, with Mali, Guinea, Burkina Faso and the RCI (Republic of Côte d'Ivoire) as partners would be, as it were, the relevant continuation in the medium-term of this type of action. A subregional strategy for controlling this type of pest which is capable of covering short distances under its own steam (directed flight) or being carried over long distances by the violent winds of the ITF coming from the south (undirected flight) is, in fact, taking hold.

  Sponsors who could be contacted for this project, through the IER, are the SCAC, and particularly the EU within the framework of the discussion of the 9th EDF, for example during the year 2001.

CONCLUSION

This research and control project, undertaken by the CAE vis-à-vis the Tephritidae fruit flies of the mango tree in Mali, has yielded innovative results on a scientific level, interesting in terms of applied research, and promising for the planters ; these results will need to be confirmed over the years to come.

The bibliographical data which we had on the entomocoenose of the Tephritidae of the mango tree and their natural control agents has grown substantially, increasing from 3 to 6 species of primary pests of mangoes ; indeed, the species *C. anonae, C. quinaria* and *C. ditissima* had heretofore not been recorded in Mali. For the larval-pupal parasitoids (micro-hymenopterae), over 80% of the material gathered seems never to have been recorded by Mali.

The damage which we had estimated by fruit sampling is not as high for the exportable varieties (Kent, Keitt) as initial predictions might have led us to suppose. Nevertheless, it remains considerable, with 30 – 50% damage owing to fruit flies having been recorded on control plots.

Trapping has (predictably) yielded excellent results, which enable us to recommend the general use of terpinyl acetate to detect and evaluate the male populations of the main species of Tephritidae at the outset of and during harvest. Within the framework of our recommendations, we advocate researching 6 other sites in addition to the 3 known ones in order to extend our monitoring and alert network in the southern zones of the Third Region.

Spot treatments have yielded encouraging results, but it has not been possible to test them under optimum conditions, since they were begun once the harvest was underway, instead of at the start of the harvest as required. From the outset of the harvest in 2001, they should be started up again in the orchards of the planters with whom we worked this year, and possibly tested in other potential sites (Sélingué, Yanfolila, Nyessoumala).

The training sessions revealed a truly remarkable enthusiasm and openness on the part of the planters which me must not subsequently disappoint. It is therefore crucial to ensure that these actions are pursued and extended at Third Region level, in liaison with the competent departments of the Malian IER.

The logical follow-up for this type of action would be the creation of a Regional Project for controlling the Tephritidae of the mango tree in West Africa, with Mali, Guinea, Burkina Faso and the RCI as potential partners. The elaboration of a subregional control strategy is crucial in the medium term as regards a subregional pest.

TABLE OF THE MAIN ACRONYMS

ACP	Countries of the Africa, Caribbean and Pacific group
APROFA	Agence pour la Promotion des Filières Agricoles [Agency for the Promotion of the Agricultural Subsectors]
CAE	Centre Agro-Entreprise [Agribusiness Center]
CIRAD	Centre International de Recherche Agronomique pour le Développement [International Center for development-oriented Research in Agriculture]
DRA	Division de la Recherche Agronomique [Agronomic Research Directorate]
FAO	Food and Agriculture Organization of the United Nations
EDF	European Development Fund
ITF	Inter-Tropical Front
IER	Institut d'Economie Rurale [Institute of Rural Economy]
IPM	Integrated Pest Management
SCAC	Service de Coopération et d'Action Culturelle [Department of Cooperation and Cultural Action]
SPV	Service de Protection des Végétaux [Department of Plant Protection]
EU	European Union
USAID	United States Agency for International Development

BIBLIOGRAPHY

- Barbet A., 2000. Suivi des populations de cératites (Dipt. Tephritidae) en Nord Côte d'Ivoire dans la perspective d'une lutte raisonnée. Mémoire présenté au CNEARC en vue de l'obtention du Diplôme d'Ingénieur des Techniques Agricoles des Régions chaudes; 52 pp. + appendices.

- Coulibaly B., 1999. Evaluation du potentiel agricole de la filière mangue en 3^{ième} région. Mali Yiriden. Agence pour la Promotion des Filières Agricoles ; 66 pp. + appendices.

- Delvare G. et Aberlenc H.P., 1989. Ordre Diptera. In : Delvare G. et Aberlenc H.P. Les insectes d'Afrique et d'Amérique tropicale ; clés pour la reconnaissance des familles ; 229-263. Prifas-CIRAD, Montpellier, France.

- De Meyer M., 1998. Revision of the subgenus *Ceratitis* (*Ceratalaspis*) Hancock (Diptera Tephritidae). Bulletin of Entomological Research, **88**, 257-290.

- Etienne J., 1982. Etude systématique, faunistique et écologique des Téphritidés de la Réunion. Thèse de l'Ecole pratique des Hautes Etudes, Paris, 100 pp.

- Hancock D.L., 1984. Ceratitinae (Diptera Tephritidae) from the Malagasy subregion. Journal of the Entomological Society Southern Africa, **47**, 277-301.

- Hancock D.L., 1987. Notes on some African Ceratitinae (Diptera Tephritidae) with special reference to the Zimbabwean fauna. Transactions of the Zimbabwe Scientific Association, **63**,47-57.

- Ito Y. et Koyama J., 1982. Eradication of the melon fly : Role of population ecology in the successful implementation of the sterile insect release method. Protection ecology, **4**, 1-28.

- Kapatos E.T., 1989. Integrated Pest Management System of *Dacus oleae. In* World Crop Pests-Fruit flies : their Biology, Natural Enemies and Control. A.S. Robinson & G. Hooper (eds), Elsevier, Amsterdam, 3B, 391-396.

- Marchés tropicaux et méditerranéens. Spécial Mali ; 2842, 715-736.

- N'Guetta K., 1994. Inventaire des insectes de fruits récoltés dans le Nord Côte d'Ivoire. Fruits, **49**, 5-6 : 502-503.

- N'Guetta K., 1998. Rapport d'activité de recherche. IDEFOR / DFA, 12 pp.

- Noussourou M. et Diarra B., 1995. Lutte intégrée contre les mouches des fruits. Sahel IPM, **6**, 2-13.

- Nonveiller G., 1984. Catalogue des insectes du Cameroun d'intérêt agricole. Institut pour la protection des plantes, Mémoires XV, Belgrade, Yugoslavia.

- Quilici S., 1992. Renforcement et stimulation de la lutte raisonnée contre les mouches des fruits. Rapport annuel CIRAD / IRFA. 8 pp.

- Quilici S., 2000. Compte-rendu de participation à la première réunion du programme coordonné FAO-AIEA « développement d'attractifs optimisés pour les mouches des fruits », Sao Paulo, Brazil, 28 / 08 au 1 / 09 / 2000.

- Silvestri F., 1913. Viaggio in Africa per cercare parassiti di mosche dei frutti. Bolletino del Laboratorio di Zoologia Generale e Agraria della R. Scuola Superiore d'Agricoltora, Portici, **8**, 1-164.

- Southwood T.R.E., 1978. Ecological methods with particular reference to the study of insect populations. 2nd edition.Chapman and Hall, London, 524 pp.

- Vayssières J.F. & Sangaré M., 1995. Enquête sur le potentiel de production de mangues en Haute Guinée. Projet FAC / IRAG. Ministère du Développement Rural. Conakry. Guinea 18 pp. + appendices.

- Vayssières J.F. & Carel Y., 1999. Les Dacini (Diptera Tephritidae) inféodées aux Cucurbitaceae à la Réunion : gamme de plantes-hôtes et stades phénologiques préférentiels des fruits au moment de la piqûre pour des espèces cultivées. Annales de la Société Entomologique de France, **35**, 197-202.

.

- Vayssières J.F. & Kalabane S., 2000. Inventory and fluctuations of the catches of Diptera Tephritidae associated with mangoes in coastal Guinea. Fruits, **55** , 259-270.

- Vincenot D., 1993. Synthèse de trois années d'expérimentation et de développement en lutte intégrée sur agrumes à l'île de la Réunion. Document CIRAD-FLHOR / C.A. de la Réunion, 36 pp. + appendices.

- White I.M. & Elson-Harris M., 1992. Fruit flies of significance : their identification and bionomics, CAB international with ACIAR, Redwood Press Ltd, Melksham, U.K., 601 pp.